Chapter 7
Data Management, Analysis, and Reporting

7-1. Introduction

Data management and analysis are crucial to understanding the behavior of a monitored structure, for detecting unsafe developments, and for determining the performance of the instrument systems. The major aspects of the instrumentation planning process are data management, engineering analysis, and formal reporting. A plan for the management and analysis of data should be in place before the instruments are installed. The plan should indicate the frequency of data collection, the extent and timeliness of processing, the level of analysis, the reporting requirements for in-house engineers and reviewing authorities, and the people responsible for accomplishing each of these tasks.

7-2. Data Management

The management of data consists of data collection, reduction and processing, and presentation.

a. Data collection. Data collection should begin with a well-defined established schedule. The schedule is dependent on project-specific requirements. The requirements are dependent upon instrument characteristics, site conditions, construction activity, or the occurrence of unusual events. The schedule should be updated whenever these conditions or instrument readings indicate the need. Data collection procedures should adhere to the following guidelines:

(1) Personnel consistency. Data will be most consistent if collected by the same person. If this is not possible the designated instrument reader should have a backup instrument reader who is also familiar with the instruments. Data collection personnel should read the instruments in the same manner every time.

(2) Instrument consistency. Using the same readout unit to read an instrument every time will give the most consistent readings. The readout instrument should be connected or aligned the same way for every reading. Readout units should not be interchanged, because readings can be dependent on readout unit and transducer combinations.

(3) Multiple readings. Multiple readings should be taken to the most representative value.

(4) Coordination of instrument readings. Instrumentation systems should be designed to have different types of instruments show changes under the same conditions and in the same time frame. Therefore, the instrument whose values, which need to be compared, should be read as close to the same time as possible.

(5) Data records. Instrumentation data should include the instrument reading and also any information that identifies the project, instrument, readout unit, reader, date, visual observations, climate, remarks, and any site conditions that might affect the value of the reading. All calibration checks, averaging, or median values should be shown. Data from field books or field data sheets should be transferred to data calculation sheets or data computer files and the originals filed.

(6) Data entry. Recording readings in field books allows for comparison of current readings with previous readings at the time the readings are collected. This early or initial comparison of the data aids in assuring the correctness of the readings and also allows for early detection of problems with instruments so that corrective action can be implemented without delay. The readings in field books should be transferred to data sheets or computer files as soon as possible after being obtained, to avoid losing data if the field book is lost or destroyed. The transfer should be checked for transposition errors. Field data sheets used to record field readings directly should be forms with spaces for recording all the factors necessary. Field data sheets should include previous readings for immediate comparison with current readings, or a copy of previous readings should be available for current reading comparison, as a first step in data management. Portable data acquisition recording devices are helpful in transmitting data. These devices may save time and minimize errors.

(7) Communication. Communication among personnel responsible for data collection, data processing, data reviewing, and data analysis is vital to the data acquisition process. The data collection personnel should communicate to the data review and analysis personnel all conditions that could affect the readings. The data review and analysis personnel should communicate the results of their work to the data collection personnel to indicate whether the instruments are being read correctly, if the instrument is operating correctly, if the reading schedule is adequate, etc.

(8) Warning of unusual conditions. Readings that exceed established threshold levels should be reported

immediately. Appropriate personnel should be notified when an instrumentation reading, changed condition, activity, or visual observation reveals that a problem or dangerous situation has occurred, or is occurring, and implement the steps listed in the Project Operation and Maintenance Manual, Emergency Contingency Plan. Communication and cooperation among all parties involved in data acquisition is essential, especially when problems arise.

(9) Special considerations of automated data collection. Automated data collection allows for the adjustment of the data collection frequency to capture the behavior during a significant event. For example, if an event at a project causes a rapidly fluctuating reservoir elevation, the data collection frequency should be altered to record the effect of the event. Automatically recorded readings that are beyond threshold values should be checked. This early or initial check of the data aids in ensuring the accuracy or correctness of the readings and also allows for early detection of problems with instruments so that corrective action can be implemented without delay.

b. Data reduction and processing. Data processing and reduction consists of converting the raw field data into meaningful engineering values necessary for graphical presentation, analysis, and interpretation. Several calibration constants may be needed to convert the field readings to engineering values. In the past, these conversions were performed by hand, but currently can and should be performed by computers to eliminate conversion errors. Where possible, initial and preliminary reduction and processing of instrumentation data should be accomplished in the field, where anomalous readings, errors, or malfunctioning instruments can be readily identified and/or corrected.

(1) Timeliness of data reduction and processing. Expeditious transfer of instrumentation readings from the project site to the reducing/processing/reviewing office is essential in timely data management. Facsimile machines, local computer networks, or express mail services should be used to expedite data transfer. All instrumentation data should be reduced and processed as soon as possible, preferably while the conditions under which the data were obtained still exist (e.g., reservoir stages, high velocity flows). Backlogging or stockpiling of instrumentation data for later reduction and processing prior to preparation for annual data submittal or scheduled inspections is unacceptable.

(2) Error checking. Checking for errors in instrumentation data should be accomplished at each level of collection and processing (from reading of instruments in the field to final interpretation of the instrumentation data). Checking should commence with proofreading of data values to ensure that readings have been properly recorded on field data sheets or notebooks and transcribed correctly from field data sheets or notebooks to reporting forms or summary tabulations. Instrument readings should be compared with ranges specified by the reviewing office and with previous readings under similar conditions. Conformance with previously established trends should be determined. Anomalous readings should be identified and checked as necessary. Data sheets should reflect the anomalous readings and possible causes of such readings.

(3) Reduction and processing methods. Simple computer programs should be used to expedite data reduction. Careful proofreading of input values is recommended, and a standardized input format should be used. Programs which are used to reduce instrumentation data should be carefully tested and verified by the user to ensure that they are operating correctly throughout the expected range of instrument values. These computer programs range from simple programs which perform only data reduction calculations to complex databases designed for data reduction of many different types of instruments. The more complex databases can be used for data storage on electronic media, production of plotted data, some preliminary analyses, and maintaining history files of instrument readings. It is recommended that computer programs be used for data reduction, data storage, and graphical plots. Regardless of the computer program used, periodic manual checking of data calculations and results by knowledgeable instrumentation personnel is essential. As with any computer system, a procedure or time frame for backing-up the data is an essential step in data processing. A relational database, such as the Instrumentation Database Package developed by the Corps of Engineers, is helpful in all phases of data management.

c. Data presentation. Numerically tabulated data are not conducive to detecting trends, evaluating unanticipated behavior, and comparison with design values. Plots of the data are needed to provide visual comparisons between actual and predicted behavior, a visual means to detect data acquisition errors, to determine trends or cyclic effects, to compare behavior with other instruments, to predict future behavior, and to determine instrumentation maintenance requirement needs. Plotting enables data to be compared readily with events that cause changes in the data, such as construction activities and environmental changes. Plotting also provides a visual means to evaluate unanticipated behavior, and to determine the effectiveness of remedial correction.

(1) Types of plots. Several types of plots can aid in evaluating various project conditions. Some examples are given below.

(a) Time history plot. Time history plots display time versus the change in parameter (see Figure 7-1). Parameters such as water level, seepage, pore water pressure, deformation, and temperature can be plotted against time. Dual Y-axis time history plots allow the plotting of a second parameter, such as pool, tailwater, or rainfall, with the first parameter.

(b) Positional plot. Positional plots show a change in parameter (water level, temperature, deflection, etc.) versus the position of an instrument (see Figure 7-2). These positions can be shown as cross section, X-Y coordinate, station, offset or depth. An example of a positional plot is an inclinometer plot as shown in Figure 7-2. This type of inclinometer plot shows horizontal deformation versus depth and changes with time.

(c) Other plots. Multiple plots and plotting of multiple parameters is possible. An example is Figure 7-3. Plotting multiple parameters can be useful in examining questionable conditions.

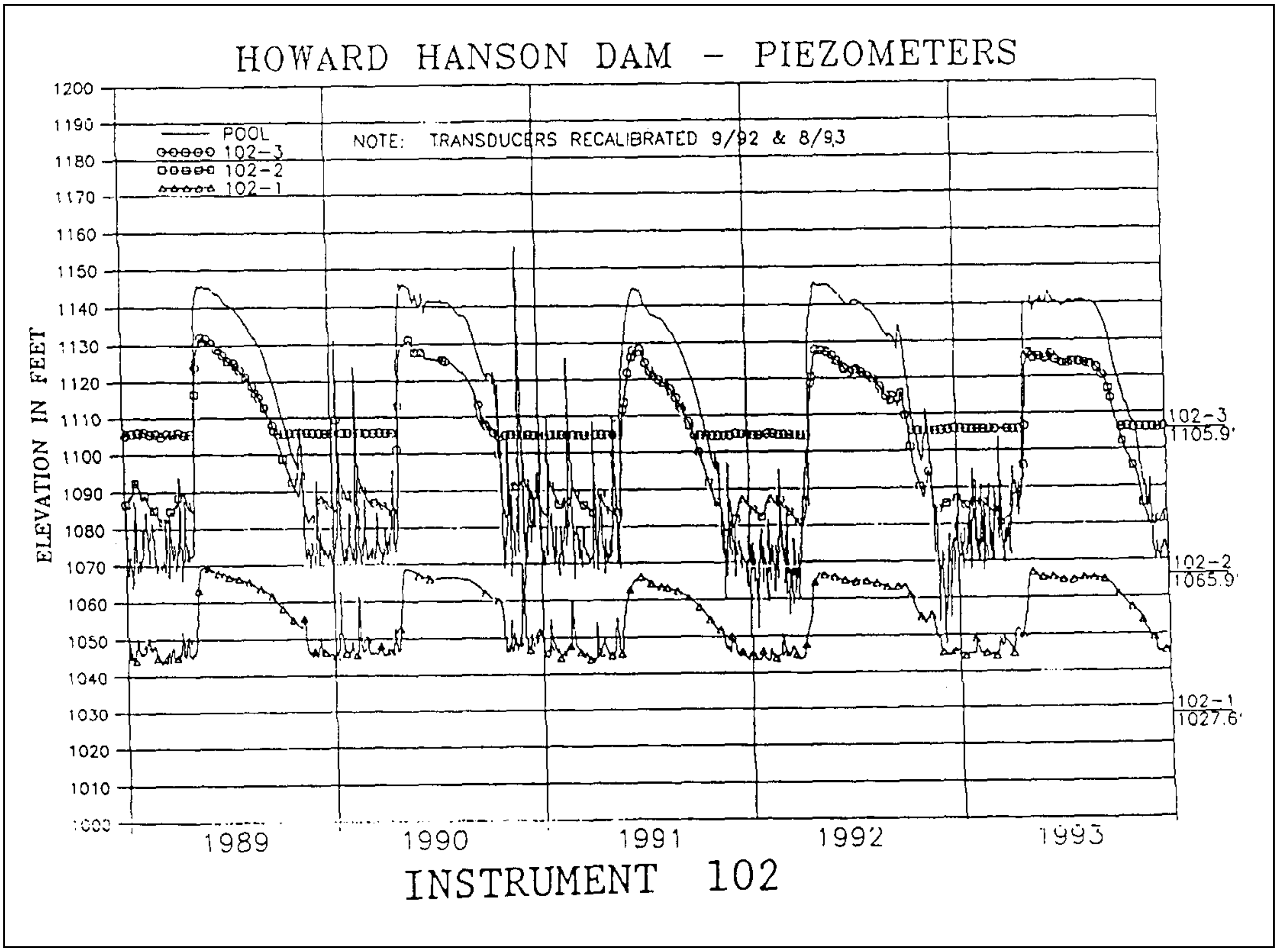

Figure 7-1. Example of a time history plot

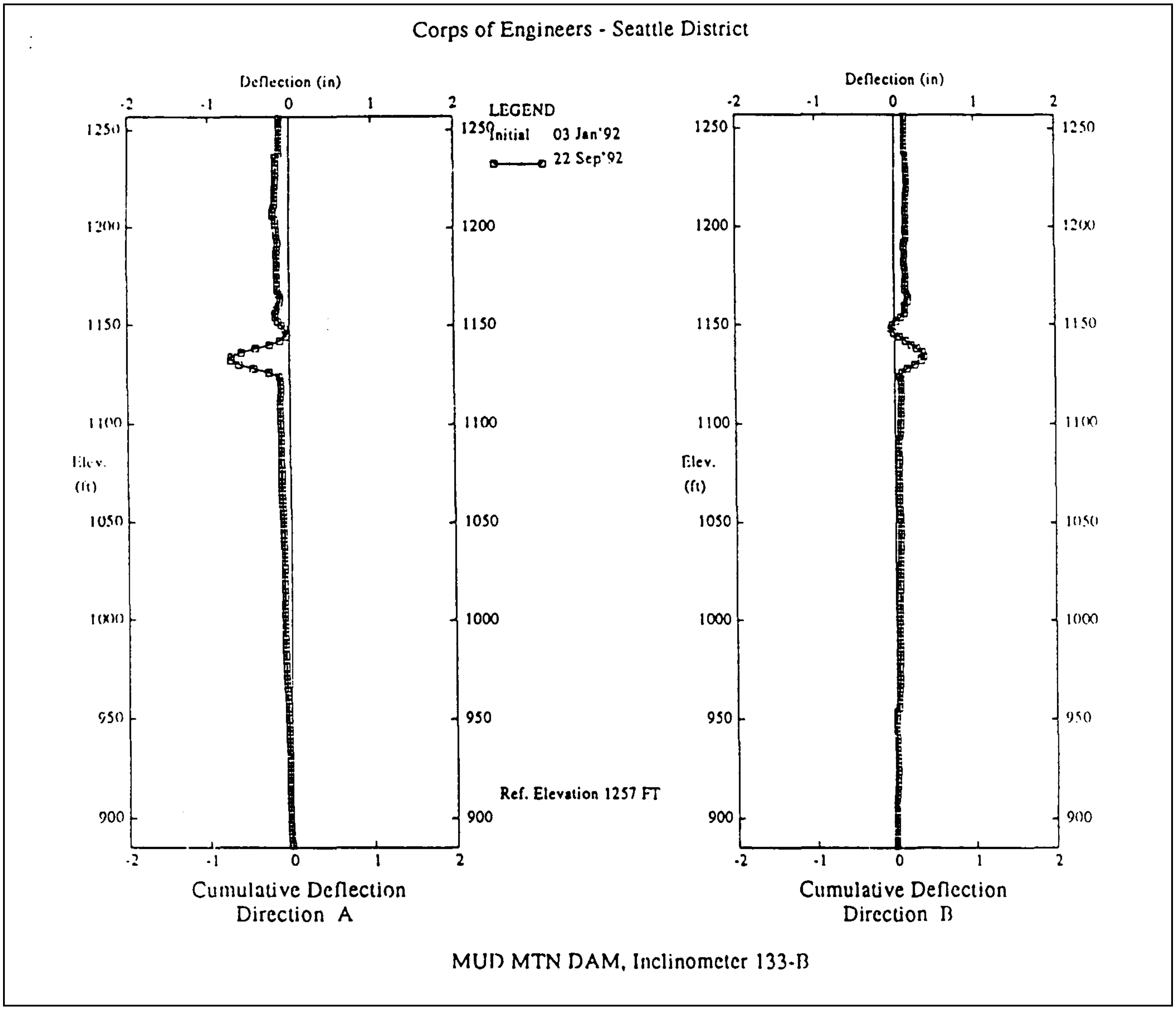

Figure 7-2. Example of a positional plot

(2) Guidelines for plotting. Some guidelines for plotting follow:

(a) Appropriate scale should be chosen for the analysis. Determination of minute changes requires a scale of small increments. Scales with increments so large that they would not show the data trends should not be used. Exaggerated scales that would magnify minor changes to make them appear alarmingly large should not be used.

(b) Standardize the graph formats and scales for all the projects or features as much as possible to minimize confusion and effort of interpretation.

(c) Location and cross-sectional sketches should be included on the graph to orient the reader to the subject area.

(d) Multiple graphs should be used to explain a situation by showing related conditions.

(e) If appropriate, the predicted behavior and/or limits of safety values should be shown along with the actual monitored behavior.

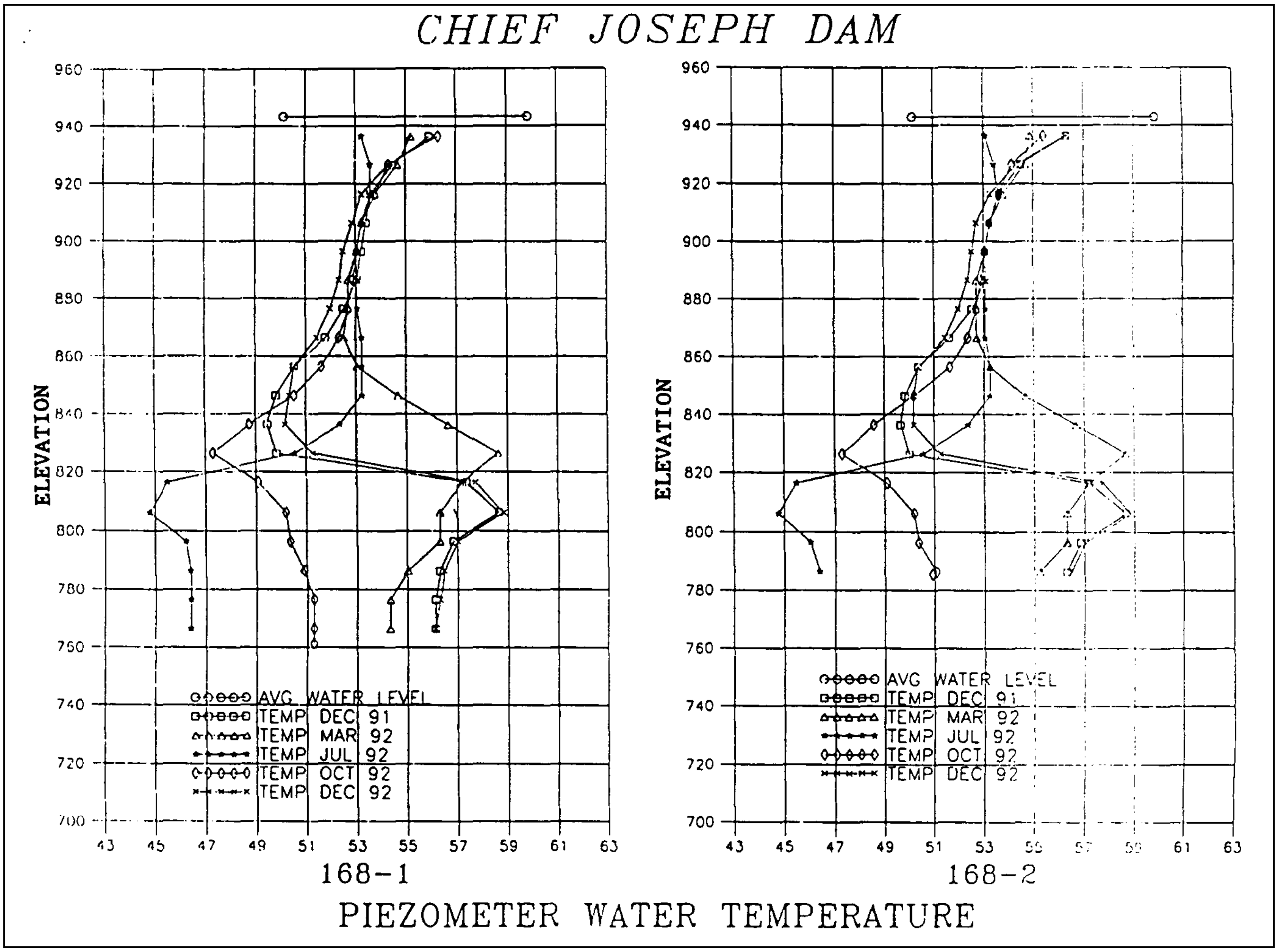

Figure 7-3. Example of a multiple parameter plot

(f) Significant influences of the measurements should be noted (i.e., construction activities, reservoir level on piezometer level plots, temperature on expansion/contraction plots).

7-3. Engineering Analysis

Data analysis is the interpretation and evaluation of the data as affected by various conditions. It is a continuous process from data collection through reporting. At every step of the analysis, the evaluator should be conscious of the potential for invalid data and the improper use of the calculations, so that incorrect interpretations are not made. Proper analysis will address two basic aspects of dam safety monitoring: the performance of the instrument system, and the performance of the structure or feature that is being monitored.

a. Timeliness of data. The field reading should be compared to the previous data set as it is recorded in the field. Data should be entered into the computer by electronic transfer or immediately upon returning to the office. The computer should have an automatic check to determine the significance of value variations upon entry. Questionable results of either of these two procedures should be brought to the immediate attention of the instrumentation program manager. Reduced data in plot format should be immediately reviewed upon completion of processing. In-depth analyses should be accomplished commensurate with the degree of concern associated with the monitored feature. Reduced data should be provided to other involved offices (hydraulics, structures, operations, etc.) as appropriate. Under normal circumstances with conscientious attention by qualified personnel, significant dam safety concerns can be detected within hours;

valid and meaningful information and preliminary analyses can be made available within one day, two days maximum. The severity of the situation can accelerate the assessment.

b. Analysis techniques. An analytical technique can be considered the viewing of the current information in the context of past experience. It should also consider the predicted behavior of the monitored feature. The review and analysis personnel should consider the following techniques when analyzing the data.

(1) Compare current data with the most recent data set to detect anomalies, discernible short-term behavioral changes, and instrument malfunctions.

(2) Compare the current data point with historical performance over a significant period of time to ascertain consistency of instrument performance for the monitored feature. This can also indicate compliance of the new information with an established trend.

(3) Compare current data point with the initial reading for that point to determine the magnitude of change over time. This can indicate instrument drift or fundamental characteristic behavior of the structure.

(4) Compare trends of behavior over time with trends predicted during design, with values relating to calculated factors of safety, and/or with any other predicted behavior. Note that the historic behavior of a structure becomes the base for comparison of future behavior and the performance predicted during design becomes less relevant.

(5) Compare the results of one instrument system with those of complementary systems to confirm or deny an implied physical change (e.g., consolidation settlements with dissipation of pore water pressure, pore water pressures with functioning of drains).

(6) Use statistical analyses to assess the performance of instruments. Automated systems can acquire a large quantity of data which is conducive to calculating standard deviations and variance of instrument response. This is also helpful in determining calibration frequency.

c. Outcome of data analysis. There are many outcomes of data analysis. The appropriate personnel should consider the following:

(1) Determine when to test, calibrate, or abandon instruments.

(2) Determine if the schedule of observation should be altered.

(3) Reevaluate which areas of the project require priority attention.

(4) Determine the need for further study (slope stability, seepage, and other structural performance analysis).

(5) Confirm or refute previous studies.

(6) Prepare the processed data for formal presentation and develop the engineering position that will be reported.

d. Pitfalls to avoid. The following are some data pitfalls to avoid:

(1) Lack of data comparison in the field resulting in invalid data.

(2) Delaying data entry, analysis of processed data, and the dissemination of information to involved offices.

(3) Assuming data are valid and calculations were executed properly. Software calculation and calibration factors should be periodically checked.

(4) Assuming that change in data is reason for concern. Instrument may be appropriately responding to a condition.

(5) Assuming no change is satisfactory. Instrument may not be operating.

(6) Failing to recognize or incorporate all factors that influence the data (e.g., seasonal temperature changes affecting structural movement, temperature, rainfall, reservoir level values).

(7) Assuming contour plots are accurate. Those plots developed by automation or computer software should not be used without a careful review by an experienced geotechnical engineer or geologist who should be thoroughly familiar with the software.

7-4. Formal Reporting and Documentation

Formal presentation of data may be quite different than the plotting prepared for data analysis. Formal presentations summarize and present data to show trends, enable comparison of predicted design behavior with actual behavior, document key aspects of the instrumentation monitoring program, and identify necessary remedial measures. Reporting requirements are contained in a variety of regulations and formal reporting guidance. As the reporter complies with these regulations, consideration should be given to the following:

a. Choose the aspect of performance that is to be portrayed.

b. Identify all conditions and information that significantly enhance the portrayal.

c. Group instruments that are pertinent (e.g., cross section of foundation piezometers only) to relate to cutoff effectiveness.

d. Refrain from using formal reports to serve as a depository for permanent filing of all data ever acquired. The focus should be on reporting the condition that is monitored.

e. Scales for the data presentation used for analysis (see 7-2*c*(2)) may show detailed changes over a short period of time. Detailed changes over a short period of time may be desirable for analytical purposes. However, formally reported assessment of the same information may show an acceptable trend in the long-term which would require a different scale. Scales for analysis may be chosen for seeing, but the final reported assessment of the behavior may be insignificant change and in compliance with an accepted behavioral trend in the long term.

f. Focus on clarity and significance of information on plots.

g. The text of the report should discuss changes, and identify trends and rate of change with time. Specific values should be stated in units that are meaningful and understandable. A specific statement should be made with regard to the engineering judgment of the situation, the acceptability of the condition, and the intentions for followup.

h. Guidelines for plotting in paragraph 7-2*c* are also relevant for formal reporting.